THE EFFECT OF PHONOLOGICAL WORKING MEMORY ON CHILDREN'S CHINESE SPOKEN WORD LEARNING

BY

JUNLI WEI

THESIS

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Master's Committee:

Professor Richard Anderson, Chair
Professor Adele Proctor
Professor Jerry Packard

ABSTRACT

The purpose of this study was to investigate how well English speaking children's phonological working memory can predict their ability to learn Chinese spoken words. Standard Chinese (Mandarin) is considered in this study and thus both terms (Chinese and Mandarin) will be used interchangeably. Participants included a total of 32 fourth grade American children who spoke English as a first language and attended primary school in the Midwestern region of the U. S. A battery of measures was administered orally to test children's phonological working memory and Chinese word learning ability. The results showed that the children's phonological working memory could predict their Chinese spoken word learning ability and the strongest predictors were the performance on the repetition of Chinese nonwords with tone and English nonwords without stress. These findings improve understanding of how phonological working memory underpins children's vocabulary development. Finally, these results provide insight for administrators, teachers and parents in predicting whether students have potential to learn Chinese and therefore help them make decisions accordingly. The result also has implications for teaching Mandarin to English speaking children.

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CHAPTER 1

INTRODUCTION

The phenomenon that with the same exposure to a new language, some children can learn it more efficiently than others is the focus of the present study. A critical question is whether phonological working memory can be a potential underlying factor accounting for children's individual differences in learning language.

Considerable experimental evidence has demonstrated that phonological working memory is important in the word learning of both native and foreign languages (Baddeley, Gathercole, & Papagno, 1998; Cheung, 1996; Gathercole, 2006; Gathercole & Baddeley, 1989; Gathercole & Thorn, 1998). Substantial studies showed that with same exposure to a foreign language, people with better phonological working memory could learn it more efficiently than others (Masoura & Gathercole, 2005; O'Brien, Segalowitz, & Collentine, 2007; Service & Kohonen, 1995). In addition, a deficit in phonological working memory disrupted and delayed children's language development (Gathercole & Baddeley, 1990).

In recent years, Americans' interest in learning Chinese as a foreign language has been increasing. As of August 2010, China's economy has become the second-largest in the world, with the U.S. being the first. China's rise and its telling effects politically, economically and culturally might attract more Americans' interest in studying the Chinese language (the Asia Society, http://www.chinaembassy.org/eng/xw/t205822.htm). However, Chinese is a tonal language and English is not. The phonological difference between them makes learning Chinese a challenge for English-speakers.

Phonological Differences between Chinese and English

The phonological differences between Chinese and English can be demonstrated in three aspects: phoneme difference, phonotactic difference and suprasegmental difference.

First, phoneme differences exist between English and Chinese. Many Chinese phonemes, such as zh, ch, x, etc do not occur in English. This might make learning Chinese challenging for English speakers. The present study tried to avoid using phonemes that are only unique in Chinese (such as onsets *x, zh, ch,* etc) but do not occur in English in order not to make phonemic awareness an issue. Consequently, though phonemic differences exist between English and Chinese, it should not cause difficulties in speaking Chinese in the present study.

Second, Chinese phonotactics and English phonotactics differ greatly. Phonotactics is the particular combination of letter sounds that are allowable within a given language. Each language has its own set of rules that speakers stay within. Previous research has provided some evidence for the representation of phonotactic information in memory. According to Vitevitch, Luce, Charles-luce and Kemmerer (1997),

> Phonotactics configuration may have important consequence for the representation and processing of spoken words. In particular, spoken words composed of common segments arranged in regular sequence may be processed more accurately and rapidly than words composed of less common segments and sequences (P.48).

Moreover, Brown and Hildum (1956) showed that phonotactic constraints may cause learning problems on spoken word recognition. Moreover, Auer (1993) found that words with high probability phonetic patterns were processed more rapidly than those with low probability patterns. English and Chinese are governed by different sound rules. For example, the syllable structures of Chinese are V, VC, CV, and CVC, while in English the syllable structures are far more complicated with various extended consonant clusters that consist of up to three consonants before a vowel as in the word *straight* (CCCVVC) or four consonants after the only sounded vowel in the word *scrambles* (CCCVCCCC). Thus, American children need to develop phonotactics consciousness of Chinese syllables in order to learn Chinese. However, English speakers in the present study neither knew any rules about the sequence of sounds that form a syllable nor had any knowledge about word structures and constraints. All Chinese phonotactics is arbitrary to them. Hence, when repeating Chinese nonwords, phonotactics in Chinese syllable may sound strange to them. Thus, it might take the English-speaking children longer time to master the internal structures of Chinese syllables in order to get to the same level as English on phonotactics. Consequently, even though the Chinese syllables are not phonologically complicated (the Chinese nonwords in this study are fairly simple with single consonant, especially for the 1- and 2-syllable Chinese nonwords), stringing them together into either words or nonwords is still challenging, thus making English nonword repetition might be easier than making Chinese nonword repetition. However, if a memory task of Chinese nonword repetition is so easy that only minimum involvement of phonological working memory is needed, Chinese nonword repetition will probably be more successful than English repetition.

Third, Chinese tone and English stress differ greatly. Chinese is a tone language and it uses varying pitch (highness or lowness) of a phoneme sound to distinguish word meaning. For speakers whose native language is non-tonal, tone has presented great difficulty, since Mandarin tones are manifested physically by different fundamental frequency (F0) values with F0 height and F0 contour as the primary acoustic parameters (Wang, 2006). Moreover, non-native speakers are not familiar with amplitude and temporal properties such as overall duration and turning point which are also important in perception and production of tones (Lin, 1965, as cited in

Wang, 2006). In Mandarin Chinese, there are four basic tones and a neutral tone, which correspond to characteristic pitch patterns. Tone is traditionally displayed with Chao's (1930) "time-pitch" graphs, which used a scale of one to five to divide the total pitch range in Mandarin tone into four equal intervals. The 5-point scale uses 1 representing the lowest level and 5 representing the highest level. Each tone can be labeled by giving its starting and ending pitch. The same syllable with a different tone has different meaning. For example, there are many ma syllables in Mandarin *mā* the first tone, high-level means mother [55]; *má*, the second tone, high-rising [35], means hemp; *mǎ* the third tone, low-dipping [214], means horse; *mà*, the fourth tone, high-falling [51], means scold. It is confusing that if a person wanted to say mother *mā* , but pronounced as *mǎ* (horse) instead. Therefore, tone learning is essential and one of the biggest challenges for Chinese learners.

English uses structural or segmental elements such as phonology, morphology and syntax to denote grammar. Stress patterns are overlaid on segments and referred to as suprasegmental. English stress can be shown by pitch, amplitude, and duration (Crystal, 1969). Stress syllables tend to have higher pitch and longer duration than their non-stressed counterparts. In addition, they may be somewhat louder than unstressed syllables (Katamba, 1989). In English, within-word pitch was usually used to emphasize or express emotion, not to give a different word meaning to the sound, though there are certain exceptions in disyllabic words. For example, in many disyllabic words, the location of stress depends on whether the word appears as noun or as a verb: the word is used as a noun when the stress is on the first syllable and verbs when on a later syllable (usually the second, but not always) such as *content, contract, contrast, import , record,* etc. In contrary to English stress, Chinese tone is assigned to distinguish word meaning. Tone is assigned to an entire word without association to specific syllable. Moreover, in Chinese, pitch is not the dominant feature to show stress. Instead, duration and amplitude play a more important role in Chinese (Chang, Hao & Tu, 2011).

In a review on the perception and production of Mandarin tones by native and nonnative speakers of Mandarin (Wang, Jongman & Sereno, 2006), the authors summarized the following findings: first, tone perception depends to some extent on the linguistic function of pitch in their native language; second, listeners can differentially tune their auditory system to certain physical properties of a sound as a function of their linguistic experience; third, English speakers' perception of Mandarin tones is influenced by their native intonation system such as English stress; fourth, extrinsic factors such as the speaker's F0 and speaking rate also affects nonnative tone perception.

The relation between English stress and Chinese tone is controversial. On the one hand, as mentioned above, there might be no correlation between English stress and Chinese tone. In addition, hemisphere processing theory also provided support for this view. According to the behavioral and neuroimaging research on the hemisphere processing theory, the hemisphere processing of Mandarin tones revealed that tone was lateralized in the left hemisphere for native speakers. However, English listeners' perception of Mandarin tone was influenced by their native intonation system which is dominated by the right hemisphere. Chinese tone and English stress are managed by different hemispheres of human brain, thus they were independent units at the level of phonological representation (Wang et al., 2001). On the other hand, English stress and Chinese tone might be correlated, since both English stress and Chinese tone are suprasegmental features that may affect phonological working memory. The sensitivity to prosodic features of languages might be responsible for this correlation.

With so many phonological differences exist between English and Chinese, it is unclear how easy it is for English speakers to learn Chinese after acquiring English as a first language. In an attempt to address this problem, it is important to determine variables that influence Chinese learning. Phonological differences between English and Chinese should be considered first. Since phoneme difference between English and Chinese was controlled, the phonotactic and suprasegmental differences might provide information on their role in learning a foreign language.

The present study seeks to establish the role that phonological working memory may play in acquiring Chinese as a foreign language. To answer this question, the following review first discusses the theoretical framework for phonological working memory and then explains the effect of phonological working memory on vocabulary acquisition in both native and foreign languages.

Phonological Working Memory

The term *working memory* was proposed by Baddeley and Hitch (1974) to emphasize a difference between their three-component model and earlier unitary models of short-term memory. Working memory involves the temporary storage and manipulation of information necessary for many complex cognitive activities. Baddeley and Hitch's initial proposal of a multi-component working memory model has been widely accepted and continuously revised (Baddeley, 1986, 1993, 2001, 2003). It also served as a theoretical foundation for the present study.

Prior to Baddeley, the unitary model proposed by Atkinson and Shiffrin (1968) is most influential. According to this model, information was come from environment, processed by a series of temporary sensory memory systems, and then stored in the limited capacity of short-term store. The short-term store feeds information into and out of the more durable, long-term memory store to support complex cognitive activities (Baddeley, 2006). Criticisms of the unitary model came from its long-term learning assumptions. For example, Baddeley (2006) argued that little evidence could show simply holding information in short-term store would facilitate learning, because degree of learning depended on the way in which information was processed (p. 4). Moreover, patients with short-term memory impairment showed few cognitive problems, which was contrary to the assumption of this model, since it stated that those patients should show little capacity for everyday cognitive activities or for long-term learning.

The focus of the present study is on the phonological loop, a subcomponent of working memory specialized for temporary maintenance and processing of verbal material *(*Baddeley & Hich, 1974). It consists of two subcomponents: a temporary storage system that holds in phonological form and a rehearsal process serving to maintain decaying representation in the phonological store. The phonological short-term store is a primary language learning device, though rehearsal might be important for maintaining the quality of stored information. The rehearsal can refresh the phonological traces in the short-term store to offset decay. So, the short-term store and the rehearsal process are semi-independent and they work together to deal with memory tasks (Gathercole & Baddeley, 1993). It is important to note that previous studies used different terms for phonological working memory, such *as phonological short-term store*, *verbal working memory*, *phonological memory*, etc. The present study used the term *phonological working memory* in Gathercole and Baddeley (1993) and mainly focused on studying its role in language learning. The phonological capacity is limited by number of chunks rather than items, with different material being more or less chunkable (Miller, 1956).

The *phonological similarity effect* and *word length effect* (Baddeley, 2003) can help demonstrate the nature of phonological loop. The phonological similarity effect showed evidence for phonological store and the word length effect showed rehearsal, on the assumption that "longer words take longer to articulate during rehearsal, allowing a greater degree of trace decay and resulting in poorer performance" (Baddeley, 2006, p. 7).

Based on Baddeley's working memory model(2000), the four components: the phonological loop, the visuospatial sketchpad, the central executive, and the episodic buffer work together as a mental workspace for maintenance and manipulation of information that is necessary for performing cognitively complex tasks(Anderson, Zhang, Lin, Wei &Wu, in press). Altogether, complete and accurate phonological representations in working memory are crucial for vocabulary growth and language comprehension (See reviews, in Baddeley, 2003, and Daneman & Merikle, 1996).

Digit span and nonword repetition have been widely used to measure phonological working memory capacity. Though the two tasks are correlated and both share a positive association with vocabulary knowledge, previous studies thought that nonword repetition can provide a purer measure of phonological loop capacity, because it presumably offers individuals less chance to rely on long-term lexical knowledge for help in recall than do the more familiar items used in digit span (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1993). Moreover, nonword repetition was a reliable indicator of language skills for children as young as two years old in that it required no semantic or grammar knowledge. Also, it made use of phonemes that should be well developed in young children in natural language situation (Gathercole & Baddeley, 1990, 1993). As found by Gathercole, Willis, Baddeley and Emslie (1994), children's nonword repetition performance showed links with three important language abilities: vocabulary acquisition, reading, and language comprehension during the early school years (p. 124).

Phonological Working Memory in Early Vocabulary Acquisition

Reliable correlations between phonological working memory and vocabulary acquisition have been obtained in previous studies (Gathercole & Baddeley, 1990; Gathercole, Willis, Emsile, & Baddeley, 1992). Specifically, there is substantial evidence for association between children's early vocabulary learning and their skills in phonological working memory (e.g Baddeley, 1986; Gathercole, Brown, & Pickering, 2003). Early vocabulary reading refers to children aged below 5 years old. The importance of phonological working memory in early native vocabulary acquisition can be shown from the following two aspects.

First, phonological working memory is important in developing the phonetic recoding strategy necessary in the early reading (Gathercole & Baddeley, 1993). In phonetic recoding, the written word is translated into its component sounds and held in short-term store. If this short-term store functions efficiently, then additional cognitive resources become available for blending individual sounds together to produce a word and thus enable the appropriate meaning to be retrieved from long-term memory (Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993). As Gathercole (2006) explained,

> Letters are sequentially converted into sounds, and the latter have to be temporarily stored until the last letter has been translated. Then, the full sequence of sounds can be blended into a word (p. 40).

Similarly, Gathercole and Baddeley (1993) stated the importance of phonological working memory in early reading,

> In order to identify a target word by applying grapheme-phoneme rules to an unfamiliar letter string, the child has to store the generated sound segments, and then to blend them phonologically. . . . If the phonological loop is used for this purpose, we might indeed expect that children with very poor phonological memory function will not be very

> successful in sounding out unfamiliar letter strings and blending them to produce a word. (p.172)

Liberman, Mann, Shankweiler, and colleagues (1982) found that poor readers performed significantly less well than good readers on repeating both phonologically familiar and unfamiliar words, indicating the role of phonological working memory in children's early reading. Moreover, the word length effect and phonological similarity effect have been replicated in several studies, which showed the contribution of immediate memory to language learning (Baddeley, Thomson & Buchanan ,1975; Hitch &Halliday,1983;).

Second, phonological working memory might mediate long-term storage of phonological information. Since 1960s, it has been controversial as to whether long-term learning might depend on temporary short-term storage. Baddeley, Papagno and Vallar (1988) concluded that short-term phonological storage was important for learning unfamiliar verbal material, but was not essential for forming associations between meaningful items that are already known. Service (1992) found that Finnish children's quality of long-term memory representation is correlated with the quality of the temporary memory trace. The possible reason was explained by Gathercole and Baddeley (1993),

> One possibility is that phonological memory contributes to the long-term learning of the letter-sound mapping rules that are necessary for the use of a phonological recoding strategy. . . . The idea here is that phonological memory may play a similar role in the long-term learning of grapheme-phoneme correspondences: children with poor phonological memory skills may encounter difficulties in building the required stable associations that would enable them to map letters onto sound in word decoding (p. 171)

These studies provided important implications for studying the role of phonological short-term store in children's acquisition of foreign vocabulary.

Similarly, Gathercole and Baddeley (1989) stated, "phonological short-term memory may mediate the long-term storage of phonological information which is involved in vocabulary development. (p. 211)", thus they concluded that phonological memory was crucial in 4 to 5 years old children's vocabulary development. Moreover, Gathercole and Baddeley (1990) showed that 5 and 6 years old children with low repetition performance on nonwords were slower at learning unfamiliar names, though they had no difference in learning speed for familiar names. They concluded that children's difference in short-term memory caused their difference in long-term retention. Altogether, these studies showed that the ability to repeat and produce rehearsal of novel words in phonological working memory promotes long-term consolidation and retention.

Another example of the mediating role of phonological working memory in long-term storage was from Baddeley(1990). Baddeley demonstrated that 4 years old children's phonological short-term memory span predicted their first language vocabulary size one year later, even when prior vocabulary levels were considered. This finding suggested that representation of novel sound of a new word in phonological short-term memory promoted its longer term consolidation both for later articulation and as an entity with which meaning can be associated. Moreover, Gathercole, Willis and Baddeley (1991) concluded that short-term phonological working memory played a role in long-term phonological learning by showing that 4 and 5 years old children's ability to learn new words was closely associated with their skills at temporarily retaining phonological material, conditional on age and non-verbal intelligence difference. Therefore, it is well established that the process of long-term phonological learning of new words is based on the temporary phonological record provided by phonological working memory (Baddeley, Papagno, &Vallar, 1988; Gathercole & Baddeley, 1989).

Despite substantial evidence for the importance of phonological working memory in both native and foreign vocabulary learning, there are inconsistencies from previous studies. One issue is whether the effect of phonological working memory in learning vocabulary is age-related. Specifically, it is whether a role shift exists when investigating the effect of phonological working memory on vocabulary development. Gathercole, Willis, Emslie & Baddeley (1992) found that at age 8, the correlation between children's performance of nonword repetition and vocabulary scores was not closer as that at age 4, 5 and 6, though still significant. Probably between 4 and 5 years old phonological memory contributed significantly greater to vocabulary knowledge than existing vocabulary knowledge did. However, after 8 years old, phonological memory skills no longer provides a useful predictor of later vocabulary knowledge, probably because beyond this period, the interrelationships between phonological memory and vocabulary knowledge became more complex with the involvement of phonological awareness (Hu, 2003). However, as Gathercole et al. explained, the relationship shift between phonological memory skills and vocabulary acquisition only applied to first language acquisition.

Phonological Working Memory in Foreign Vocabulary Acquisition

The phonological working memory does not primarily retain sequences of familiar words, but processing novel speech input (Baddeley et al., 1998), especially mediating the long-term learning of novel phonological structures (Gathercole & Baddeley, 1989, 1993).
The phonological loop temporarily represents a new sound pattern and mediates the construction of a more stable lexical representation of the new sound (Gathercole & Baddeley, 1990). Therefore, consistent with previous studies (Baddeley, Gathercole & Papagno, 1998; Gathercole & Baddeley,1990; Gathercole & Thorn,1998), phonological working memory has a higher correlation with foreign language learning than native language learning.

Previous studies indicated that children's second language learning relied heavily on their phonological working memory (Atkins & Baddeley, 1998; Cheung, 1996; Gathercole & Baddeley, 1993). Some research concluded that phonology memory was a robust predictor of overall L2 achievement, particularly lexical and oral fluency development in both children and adults (e.g. Service & Kohonen, 1995). A positive correlation between phonological memory and subsequent proficiency was established in studying English as a L2 (Dufva and Voeten,1999; Service, 1992; Masoura & Gathercole ,1999). For example, in two 3-year longitudinal studies, Service (1992) produced a strong correlation between 9 and 10 years old Finnish children's ability to represent unfamiliar phonological material in working memory predicted their acquisition of English as a foreign language even 2.5 years later. Consistent with Service, Dufva and Voeten (1999) showed that phonological memory skill could predict children's overall proficiency in learning English as a foreign language.

Although a direct relationship has been established between phonological memory skills and the acquisition of foreign vocabulary, learning the sounds of new words in a foreign language imposes a heavier phonological load, since foreign language learning does not contain much meaningful information which can be remembered in chunks using existing phonotactic and morphological knowledge. Hence, children's performance is directly constrained by their phonological loop capacity. Those with poor or impaired phonological working memory would perform poorly (slower learning speed and/or inaccuracy of learning outcome) on learning unfamiliar or foreign vocabulary, though they did equally well on learning familiar new vocabulary (Gathercole & Baddeley,1990). This result suggested that temporary phonological encoding and storage skills were involved in learning new words. The findings are in line with Gathercole and Thorn (1998),

> Learning the sound structures of new words in a foreign language appears to be mediated by the phonological working memory. The phonological learning aspect of new word learning is enhanced by conditions that promote phonological loop function and impaired by those that diminish it, regardless of whether the new language learners are children exposed to a number of languages naturally in their environment, or experimental

> participants learning foreign language equivalents to familiar words in the native language (p. 151).

Thus, foreign language learning was disrupted by articulatory suppression (Papagno, Valentine, & Baddeley, 1991). In summary, the correlation between phonological working memory and foreign language vocabulary learning was robust, which is consistent with Baddeley's finding that the primary function of the phonological loop is to support language learning (Baddeley, Gathercole & Papagno, 1998).

Though most research supported the robust role of phonological working memory in foreign language learning, controversies still exist. One issue is the distance between the target foreign language and learners' native language. Previous evidence showed that existing knowledge about the structure of a language boosted the immediate memory performance for nonwords in that language (Gathercole, Service, Hitch, Adams, & Martin, 1999; Vaskevitch, Luce, Charles-Luce, & Kemmerer, 1997), since at the initial stage of foreign language acquisition, new words were learned via associations with native words, though children were able to acquire foreign words directly in later stage. It seems the ease of learning new words in a foreign language is strongly influenced by the stability of representations of native vocabulary. Similarly, Snowling and her colleagues (1991) posited that it was familiarity with structure of the target foreign language not phonological working memory that best explains the association with foreign language learning. Masour and Gathercole (1999) also concluded that shared phonological short-term memory could not exclusively account for the native and foreign vocabulary learning. If a foreign language is more similar with children's native langue, children probably have more opportunity to get support from lexical phonological knowledge in learning that language, as explained by Gathercole and Thorn (1998),

> The evidence here points to a strong relation between familiarity with a language and phonological loop function, and it indicates that temporary maintenance of novel phonological forms is likely to be constrained by the availability of both language-specific knowledge and phonological loop capacity. A consequence is that short-term retention of the sounds of new words is likely to be considerably poorer for words in an unfamiliar language than in the native tongue. Given the importance of the phonological loop in mediating long-term phonological learning reviewed earlier, new words in an unfamiliar language will therefore also be harder to learn. (p. 155)

Therefore, it is necessary to check the types of foreign languages studied in previous research to make the correlation between phonological working memory and foreign language learning more convincing.

Phonological working memory facilitates foreign-language learning (e.g., Atkins & Baddeley, 1998; Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1989). However, compared with phonological working memory research conducted on native vocabulary acquisition, fewer studies focused on foreign vocabulary learning. Moreover, available previous studies either chose foreign languages related to participants' native languages and/or selected children who had been exposed to the target foreign languages. For example, Service (1992) and Service and Kohonen (1995) studied Finnish children; Masoura and Gathercole (2005) examined Greek children; French and O'Brien (2008) investigated French children. The results in these studies all supported that the important role of phonological working memory in foreign language learning. Though children's native languages were different, they all were not phonologically distant from the target foreign language. And, participants all had been exposed to the target language before the research started.

Phonological working memory in learning Chinese

As reviewed earlier, most research investigated the phonological working memory effect on learning English as a foreign language. The specific features of a given language might determine the manifestations related to language development (Bishop & Snowling, 2004). Thus, a language that differs distinctively from English should be investigated.

To our knowledge, this study is one of the first to study the effect of phonological working memory in learning Chinese as a foreign language. Due to the unavailability of previous studies in this field, this paper can only review research on the effect of phonological working memory in learning Chinese as a native language.

Consistent with previous research (Gathercole & Baddeley, 1989, 1990, Gathercole & Thorn, 1998), the importance of phonological working memory in learning Chinese as a native language has been well-established. For example, Leong, Hau and Tse (2007) concluded that phonological working memory had strong positive effects on Chinese children's text comprehension. Their finding, "the less competent subjects had difficulty in storing information and performing concurrent processing seem to apply across writing systems to both the alphabetic English and morphosyllabic Chinese (p.91)" demonstrated that phonological working memory was critical in language development, regardless of the types of language. This result indicated the relative orthography-independent characteristic of the phonological working memory construct (Daneman & Carpenter, 1980).

On the other hand, Siu and Man (2006) found that 5 to 6-years old Hong Kong Chinese children's phonological working memory (measured by multisyllabic nonsense repetition and the sentence comprehension task) could distinguish children with specific language impairment from those with normal language development. Furthermore, correlations were observed between the number of nonsense utterances repeated and the number of elements comprehended. The result indicated that Cantonese multisyllabic nonsense repetition might work as a screening tool for the early detection of children with specific language impairment. Similarly, Liu, McBride-Chang, Wong, et al (2010) demonstrated that children with reading difficulties showed significantly impaired performance on the sentence imitation task.

Hu (2003) investigated 4-year-old Chinese children's English language learning. Hu found both phonological memory and phonological awareness may support foreign language word learning, but phonological awareness played a specific role when the words were relearned, while phonological memory could predict children's ability to learn foreign language words, regardless of whether the words were relearned or new. This finding was consistent with Baddeley et al.'s (1998) proposal that phonological memory was crucial in learning unfamiliar phonological forms. Moreover, this finding provided initial evidence that both phonological memory and phonological awareness of young foreign language learners' native language could predict their word recall and pronunciation-learning ability of a foreign language, regardless of the differences in the phonological structure and the phonemic composition of the two languages. Considering the controversy on differentiating the role of phonological awareness and phonological working memory played in language learning, this finding provided good clues for further study.

In summary, previous literature review demonstrated that phonological working memory was important in learning Chinese as a first language for native speakers, with nonword repetition being used as a relatively reliable measure (Gathercole & Baddeley, 1990). In general, phonological working memory makes a unique contribution in children's learning Chinese as a native language.

Goals of the Study

The review above demonstrated the importance of phonological working memory in language learning. A critical question is about the nature of phonological memory in foreign language study. Is it language-independent? Although the literature reveals attempts to investigate the “cross-linguistic” aspects of language processes, there has been less effort to explain whether the relationship between second-language vocabulary development and phonological memory is comparable to that observed in first-language vocabulary development. According to Chen and Leung (1989), first-language-mediation mechanism shows that first-language knowledge influenced non-native language learning: the more similar the two languages are, the higher the first language influents is on the target language. It is not clear whether previous findings of phonological working memory effect was mediated by the similarity between the target foreign language and native language, or it was purely the function of phonological working memory (Gathercole, 1995; Gathercole, Service, Hitch, Adams, & Martin, 1999; Gathercole., Willis, Emislie, & Baddeley, 1991; Snowling, Chiat, & Hulme, 1991), since most previous research used English as target language and children’s native languages were from the same or similar language family as English. Thus, if correlation between phonological working memory and vocabulary acquisition can be established between two distant languages such as Chinese and English, the conclusion of the effect of phonological working memory on foreign language learning would be more convincing. To fill the gap, the present study investigated the independent effect of phonological working memory on Chinese learning with controlling children’s previous exposure to Chinese. Moreover, it is necessary to investigate the possible correlation between English stress and Chinese tone, since each is critical in its own language system and both may be correlated with phonological working memory. If correlation between them can be established, it might lead to cross-language facilitation. However, there has been little previous effort to examine the correlation between English stress and Chinese tone.

In conclusion, the overall goal of the present study is to investigate whether and to what extent children's phonological working memory could predict their Chinese word learning. We anticipated that the children with better phonological working memory could learn spoken Chinese words more efficiently. Also, this study examined whether there was a correlation between children's performance on English stress and Chinese tone. We expected that children with a better performance on English stress would also perform better on Chinese tone. Theoretically, if the correlation between phonological working memory and Chinese learning could be established, it would strengthen the working memory theory since Chinese is a distant language from English. Investigating the relation between English stress and Chinese tone would also be beneficial in continued cross-language investigations

CHAPTER 2

METHOD

This chapter introduces the method used in this study. It first describes characteristics of participants, then explains the tests used in the present study such as how the test items were designed and scored (with a reliability check). The chapter ends with how the tests were conducted.

Participants

A total of 32 fourth-grade students from three classes across two school districts participated in the study. Participants were between 10-12 years old. Children resided in a Midwestern region of the US, represented mixed socioeconomic and educational backgrounds and thus were ethnically diverse. All spoke only American English.

Three criteria were used to select eligible participants. First, English was their primary language and they had no Chinese background, that is, no chance to speak or listen to Chinese at home. This criterion was to control participants' background experience in Chinese. English and Chinese usage at home was assessed by the home background questionnaire, which detailed their family background and former exposure to Chinese. In addition to the questionnaire, the investigator also talked to the students and their teachers to rule out any possible violations. Therefore, participants came from a homogeneous group in terms of their use of and exposure to English as their first language and Chinese as a foreign language (See Appendix B Pre-Questionnaire). Second, school records were examined to exclude the data of any participants who might have listening and speaking difficulties. This was further verified via talking with teachers of the participants. Third, fourth graders were chosen because their abilities of listening and speaking are better developed than children in earlier grades. Moreover, fourth graders have less difficulty in following instructions as compared to younger children.

Materials and Design

Participants were given a battery of tests in the following order: the Baseline English Reading Test, Auditory Digit Span Test, English Nonword Repetition Test, Chinese Nonword Repetition Test, and Chinese word learning task. For all the tests, the researchers explained what children were required to do and started the tests with several practice items to ensure that all children could follow the instructions. Two 6-minute lessons were given to introduce basic knowledge of Chinese onset, rime and tone before the Chinese Nonword Repetition Test.

Baseline English Reading Test. This subtest was used as a control for participants' initial level of English reading. It was from Gates-MacGinitie Reading Tests (Gates, MacGinitie, Maria, & Dreyer, 2000). Participants took this test as a group. They read each passage first then answered multiple-choice questions.

Auditory Digit Span Test. This test was recorded by a native American English speaker saying the numbers slowly at a rate about one number per second. Subjects were asked to recall the digits immediately in the exact order they heard them. On each trial, the digits were random and without replacement from the sequence 1 to 9, varying in length from 3 digits to 7 digits. The repetition was counted as failed if participants incorrectly repeated two lists from the three lists at each length. The final score depended on the longest length of digits that could be correctly recalled by the participants two out of three times. See Appendix C for the protocol.

English Nonword Repetition Test. The purpose of this test was to assess ability to hold phonological representations in mental storage. The stimuli consisted of 40 English-like nonwords varying in length from two to five syllables. The nonwords were taken from

Children's Test of Nonword Repetition (Gathercole, Willis, Baddeley, & Emsile, 1994) and modified by adding flat tone to each nonword. Each nonword was pronounced twice: with stress (normal way) and without stress (suppressed way). For example, a two-syllable nonword, *ballop*, should be pronounced as /ˈbæləp/ with stress falling on the first syllable, under normal conditions. If pronounced without stress, *ballop* would be read as / bæləp/ with each phoneme was equally stressed. So, the total number of original 40 nonword items became 80 and we divide them into two blocks. All the 40 nonwords were counterbalanced and displayed in both blocks but with different forms (with stress or without stress). And, in each block, half of the nonwords were pronounced with stress and another half without stress, thus if a word was pronounced without stress in Block A, then it had to be pronounced with stress in Block B and vice versa. Moreover, the nonwords in each block were presented in a random order to the participants. The stimuli were recorded in a laptop with a 3-second interval between each two nonwords. All participants listened to the recording in the school hallway, the only available space. They were asked to repeat each item immediately after listening to it. Although there was no time limit for responses, participants were expected to respond within the 3-second interval. Immediate self-corrections were credited as a correct response.

Scoring was conducted during the test and later against the recording. One point was awarded for each nonword successfully repeated. Two methods were used for scoring English nonword repetition. In Model One, performance of stress and pronunciation were combined together for scoring. Repetition of each nonword was transcribed and analyzed under two conditions: with stress and without stress. For example, nonword "*bannifer",* when read with stress, the repetition would be counted as correct only when both stress and pronunciation were repeated correctly. When read without stress, the repetition would be scored as correct when both the without stress part and pronunciation part were repeated correctly. Any mistake from either stress or pronunciation would be counted as wrong. On the contrary, in Model Two, performance of stress was scored separately from pronunciation to show the independent effect of stress in English nonword repetition. Each nonword repetition was transcribed and analyzed under four conditions: English stress (with stress), English pronunciation (with stress), English stress (without stress), English pronunciation (without stress). However, participants were only penalized for the mistakes they made in the specific situation. And, phoneme substitutions, omissions, and additions were scored as incorrect in both Model One and Model Two. Both methods used percentage score calculated by dividing the total number of nonwords correctly repeated by the total number of nonwords in that part. See Appendix D for the Protocol. The reason for using two scoring methods is to conduct finer analysis to investigate the influence of stress in English nonword repetition. Item analysis on the English nonword repetition was conducted. A four-syllable English nonword, *blonterstapin*g, was identified as an outlier (Studentized Residual = 3.10) and deleted.

Chinese nonword repetition test. The test consisted of 46 Chinese nonwords varying in length from one- to four-syllable. The number of nonwords at each length was unequal (10, 10, 20, 6), based on the result from previous pilot studies. The test started with one-syllable and then with longer nonwords. Each Chinese nonword was pronounced in two ways: with tone and without tone. The 1st tone was regarded as without tone in the present study. For example, the three-syllable Chinese nonword, *ban2 liu3 hou1* (with tone), would be pronounced as *ban1 liu1 hou1* under the situation of flat tone. Same as English Nonword, all the Chinese nonwords were pronounced with both normal tone and flat tone. And, tone and order of presentation were counterbalanced for the two blocks. In each block, half of the nonwords were with normal tone and another half were with flat tone. The items of a given length were presented in a random order. However, the Chinese nonwords were presented with the order of one-syllable first, then the two-, three- and four-syllable, so participants could get used to Chinese gradually.

Similarly as English nonword repetition, Chinese nonword repetition was scored with two different scoring methods. In Method One, the performance on tone and pronunciation were combined and the performance would be counted as correct only when tone, onset and rime were all correctly repeated. In Model Two, the performance of tone and pronunciation was separately scored to investigate the independent effect of tone on Chinese nonword repetition. The final scores in both methods were percentage scores, calculated by dividing the number of items correctly repeated by the total number of items in that part.

Item analysis showed that no outlier existed in the Chinese nonword repetition, since the highest Studentized Residual was 0.0617 (Pedhazur, 1997). In contrast to Method One, each Chinese nonword repetition was transcribed and analyzed under four conditions in Method Two: Chinese pronunciation (with tone), Chinese tone (with tone), Chinese pronunciation (without tone) and Chinese tone (without tone).It is important to note that participants were only penalized for the mistakes they made in each specific condition. All alternations in tone and phoneme productions that resulted from the use of phonological rules typical of English were scored as correct, considering that Chinese was not their native language.

Chinese word learning. This task measured the participants' ability to learn 8 Chinese words. No participants knew how to say any of these words in Chinese before the study, but they were familiar with the words in English, since all the words were frequently used such as *apple, dog*, etc. The 8 words were recorded in both Chinese and English by native speakers of Chinese and English. The recorded words were presented by a laptop computer. The participants sat closely to the laptop and were asked to listen carefully. The 8 words were divided into two groups with 4 nonwords in each group: 1 one-syllable, 2 two-syllable, and 1 three-syllable. Note: Chinese words with pronunciations difficult for English speakers were avoided, such as the onsets *x ,z ,c*. Examples of the words are: tiger (hǔ), hair (tóu fà), we (wǒ mēn), glass (bō lí bēi). The Chinese Word Learning Task was separated into three sessions: Session One for the 1st group of four words, Session Two for the 2nd group of another four words, and Session Three was final tests for the 8 words.

The procedure in both Session One and Session Two was as follows. Firstly, a study trial was conducted by playing the sound file for all words one by one, first in English and then in Chinese at each session. Then, the test trials began. The participants were asked to say each word in Chinese immediately after hearing it in English. Altogether, there were ten test trials but in each trial the words were presented in a different random order. For the first four test trials, participants did not receive feedback to their response, but whether their answer was correct or not, the answer would be played again immediately after their response. From the fifth test trial, if participants made any error in Chinese pronunciation or tone, they would be corrected immediately by the researcher until they could pronounce the word correctly. This process stopped when the participant produced no errors on three consecutive trials. Altogether, each participant was presented with 8 pairs (English and Chinese) in 10 learning trials and the order was randomized in each trial. Session Three was a comprehensive finial test, which combined all the words from Group One and Two together and aimed to find how many words students could remember. The final test was in the form of English-Chinese: the participants listened to each of the 8 words in English and tried to recall their corresponding Chinese pronunciation within 5 seconds. No feedback was given during Session Three.

Due to the scope limitation, only the final test in the Session Three was analyzed as indices of Chinese spoken word learning. Hence, in both Method One and Method two, the final score was the total number of words correctly recalled divided by the total number of words in that part . Any mistake from the onset, rime or tone would be scored as incorrect. No outlier was detected in the Chinese word learning for both models.

Reliability Check

To assist the interpretation of results, a series of internal reliability analyses was carried out on all phonological working memory measures. In Method One when putting two-, three-, four-, and five-syllable together, Cronbach's alpha values were .56 for English nonword repetition with stress (based on 40 items, from two- to five-syllable), .62 for English nonword repetition without stress (same as above), . 84 for Chinese nonword repetition with tone (based on 46 items for one-four syllable), .98 for Chinese nonword repetition without tone (same as above) and .53 for Chinese word learning (based on 16 items from one-, two-, and three-syllable).

Moreover, the performance of English and Chinese nonword repetitions was checked with subject analysis and item analysis. In general, all the tests showed internal consistency. The comparatively low reliability for English nonword repetition with stress might be explained by the possible ceiling effect caused by the two-syllable English nonword (so two-syllable was excluded from further data analysis). Item reliability was checked for each of the 8 Chinese words (16 syllables altogether) through finer analysis with pronunciation, tone and the combination of both. It displayed good composite reliability in that Cronbach alpha was .73 when combining pronunciation and tone, though it was .41 for pronunciation and .53 for tone when separating them.

For the external reliability, all the recordings were transcribed and scored by native speakers. All the raters were trained in both broad phonetic transcription and scoring rules used by the present investigation. Recordings for English/Chinese nonword repetition from audiotapes from 20% randomly selected subjects were transcribed independently by a second trained native listener on the transcription accuracy of nonwords and Chinese word learning. Phoneme-by-phoneme percentages of agreement for judgments of correctness ranged from 91-99%, with an average of 94%. The rater reliability, indexed as the agreement on the identity of nonwords and Chinese words recalled was 90%**.** Discrepancies in these observations were resolved by consultation between the raters.

For Method Two, to get the inter-item reliability of the tests used, bivariate correlation was used to compare the correlation for item- total score and item-item. The correlation between each item and total score was above .5 (for six out of eight items), though Two Chinese words: *hŭ* and *dàmĭfàn* has low correlation with the total score (.009 and .063), respectively.

Procedures

Each participant was presented with all the five tasks: Baseline English Reading, Auditory Digital Span, English Nonword Repetition, Chinese Nonword Repetition and Chinese Word Learning. The tests were divided into five testing sessions to reduce a possible fatigue effect. Except for the first test, all the others were tested individually. All the participants got the same duration time and same presentation order of the test items, etc. The participants' repetition and recall were recorded by laptop computer and later analyzed with Audacity and Microsoft Excel.

CHAPTER 3

RESULTS

This chapter analyzes data using two approaches that vary in the way the tests were scored: Approach One (combined stress/tone with syllable pronunciation) and Approach Two (stress/tone separated from syllable pronunciation). Approach One starts with the sample descriptive statistics for all the scales used, followed by the correlations between the variables. The possible relationship between syllable, language and stress/tone is analyzed. Finally, multiple regressions were conducted to identify potential predictors of Chinese spoken-word learning. Likewise, Approach Two starts with the sample descriptive statistics for the scales used, followed by the correlations between the variables, and multiple regressions to identify predictors of Chinese word learning.

The 1- and 2-syllable Chinese nonwords and 2-syllable English nonwords were not included in the final data analysis in either approach, because when they were left out, more variance in Chinese word learning could be explained. Specifically, 7.5% more variance in Chinese word learning could be explained by Approach One, and 2.3% more variance of Chinese word learning could be explained by Approach Two, when the shorter nonwords (1- and 2-syllable) were left out. Moreover, when the short nonwords were left out, Cronbach α for English nonword repetition test and Chinese nonword repetition test increased in both approaches. Therefore, including these items (1- and 2-syllable Chinese nonwords and 2-syllable English nonwords) in data analysis decreased the reliability of the study.

Approach One: Syllable pronunciation and stress/tone correct scored together

Descriptive statistics. Table 1 presents children's performance on measures of English reading comprehension, phonological working memory capacity (Auditory Digit Span, English Nonword Repetition, Chinese Nonword Repetition), and Chinese Word Learning. As shown in

Table 1, English nonword repetition with stress outperformed English nonword repetition without stress. Moreover, Chinese nonword repetition without tone outperformed Chinese nonword repetition with tone. The differences were statistically significant. The results indicate that for American children, stress may facilitate English nonword repetition while tone may hinder Chinese nonword repetition. The results further suggest that stress and tone play different roles in English nonword repetition and Chinese nonword repetition.

Correlations between variables. Correlations among the measures are presented in Table 2. First, Chinese spoken word learning significantly correlated with the Chinese nonword repetition with tone ($r = .47$, $p<.01$), with the Chinese nonword repetition without tone ($r = .39$, $p<.05$), with the English nonword repetition with stress ($r = .45$, $p<.05$), and with the English nonword repetition without stress ($r = .39$, $p<.05$). Chinese word learning had positive but not significant correlations with English reading comprehension and Auditory Digit Span. Second, there was not a significant correlation between English nonword repetition with stress and Chinese nonword repetition with tone ($r = .22$). Third, baseline English reading comprehension correlated significantly with English nonword repetition without stress ($r = .47$, $p<.01$), but not the other phonological working memory measures. Auditory Digital Span correlated significantly with most of the other phonological working memory tasks, except for the English nonword repetition with stress. Chinese nonword repetition with tone was highly correlated with Chinese nonword repetition without tone ($r = .78$, $p<.01$), probably due to content overlap.

Effects of stress and number of syllables on English Nonword Repetition. A two-way ANOVA analysis was conducted in which the independent factors were number of syllables and the presence or absence of stress. The dependent variable is English Nonword Repetition. As Figure 1 shows, English nonword repetition with stress outperformed English nonword repetition without stress, $F(1, 31) = 13.22$, $P<.001$, $\eta^2 = .12$. The results further showed that English nonword repetition performance decreases as the number of syllables increases, $F(3, 93) = 27.96$, $p < .01$, $\eta^2 = .32$. While the interaction between number of syllables and stress was not significant, simple main effects of stress as a function of number of syllables were evaluated to provide a parallel with the analysis of Chinese nonword repetition. With Bonferroni correction, the effect of stress on English nonword repetition was not marginal significant for two-syllable nonwords, $t(31) = 1.46$, $p >.10$, $d=.26$; but it was significant for three-syllable nonwords, $t(31) = 2.35$, $p <.05$, $d=.41$; and four- and five-syllable nonwords, $t(31) = 1.81$, $p <.10$, $d=.32$; $t(31) = 2.98$, $p <.05$, $d=.52$.

Effects of tone and number of syllables on Chinese nonword repetition. In order to examine the joint effect of number of syllables and tone, a two-way ANOVA analysis was conducted. As Figure 2 shows, Chinese nonword repetition without tone was higher than Chinese nonword repetition with tone, $F(1, 31) =18.15$, $P<.001$, $\eta^2=.065$. Chinese nonword repetition decreases as the number of syllables increases, $F(3, 93) = 173.70$, $p < .001$, $\eta^2=.065$. The interaction between number of syllables and presence or absence of tone was significant, $F(3, 93) = 8.59$, $p < .001$, $\eta^2=.056$. With Bonferroni correction, paired-sample t-tests indicated that the tone effect on Chinese nonword repetition was not significant for one- and two-syllable nonwords, $t(31) = -.94$, $p>.05$, $d=.17$ and $t(31) = .60$, $p>.05$, $d=.11$, respectively. However, the tone effect was significant for three- and four-syllable items, $t(31) = -3.99$, $p <0.001$, $d=.71$ and $t(31) = -3.79$, $p <0.001$, $d=.67$ respectively.

Effects of language, stress/tone, and number of syllables. A three-way ANOVA was conducted to examine the effect of language (Chinese vs. English), Chinese tone vs. English stress, and number of syllables (2, 3 and 4 syllable items). The means are presented in Figure 3.

There was no significant main effect for language, $F(1, 31) = 1.2$, $p = .28$. There was a significant simple main effect for number of syllables, $F(2, 62) = 127.69$, $p < .001$. The interaction between language and number of syllables was significant, $F(2, 62) = 47.81$, $p < .001$, indicating that with the increase in number of syllables, Chinese nonword repetition is worse than English nonword repetition. The interaction between language and tone/stress was significant, $F(1, 31) = 26.39$, $p < .001$, indicating that Chinese nonword repetition without tone significantly outperformed Chinese nonword repetition with tone while English nonword repetition with stress significantly outperformed English nonword repetition without stress (also See Figure 4). The interaction between number of syllables and stress/tone was not significant, $F(2, 62) = 2.074781$, $p =.14$. Moreover, the interaction between language, stress/tone, and number of syllables was significant, $F(2, 62) = 4.18$, $p < .05$.

A paired-sample t-test was conducted to compare English nonword repetition with Chinese nonword repetition at each syllable length by using Bonferroni correction (See Figure 5). At the two-syllable level, Chinese nonword repetition was significantly higher than English nonword repetition, $t(31) = -5.21$, $p < .001$. There was no significant difference at the three-syllable level, $t(31) = -1.65$, $p = .11$. However, at four-syllable level, English nonword repetition was significantly higher than Chinese nonword repetition $t(31) = 5.46$, $p < .001$. The result shows that with the increase of number of syllables, Chinese nonword repetition is worse than English nonword repetition (see Figure 5).

Results from multiple-regression analyses. To examine which measures are good predictors of Chinese word learning, multiple regression analyses were conducted, including factors as age, race, and family background (see Table 3). Table 3 presents the predictors and R Square change in the model. The strongest predictors by step-wise model selection were Chinese nonword repetition with tone and English nonword repetition with stress. These two factors accounts for 34% of the total variance in Chinese word learning. In this model, Chinese nonword repetition with tone entered in Step 1 and English nonword repetition with stress entered in Step 2, 22% of the total variance can be explained by the Chinese nonword repetition with tone and 12% by the English nonword repetition with stress. Considering that they both are measures of phonological working memory, there might be overlap between them, so the commonality was calculated by performing another regression analysis. This time the order of entering the model was reversed, with English nonword repetition with stress entering the model in Step 1, and Chinese nonword repetition with tone in Step 2. Then, about 20% of the variance of Chinese word learning can be explained by the English nonword repetition with stress and 14% by the Chinese nonword repetition with tone. Thus, the commonality contribution between the two predictors was 8%, indicating that 8% of the variance of Chinese spoken word learning could be explained by the overlapping part of Chinese nonword repetition with tone and English nonword repetition with stress. Moreover, the unique contribution of Chinese nonword repetition with tone was 14% and the unique contribution of English Nonword Repetition with stress was 12%.

However, an alternative model is almost as good as this model, in which Chinese nonword repetition with tone and English nonword repetition without stress were selected as predictors. Moreover, 33% variance can be explained (20% by the Chinese nonword repetition with tone and 11% by the English nonword repetition without stress). Comparing these two models, both English nonword repetition with stress and English nonword repetition without stress could predict Chinese word learning. It seemed they two had equal functions in predicting Chinese word learning. As mentioned above, stress facilitated repetition of overall English nonwords. However, further analysis is needed to investigate whether this facilitating effect applied to both English pronunciation and English stress, or only applied to one of them. Moreover, one of the research questions of the present study is to investigate the relationship between English stress and Chinese tone, hence decomposition to the stress and tone is necessary. Therefore, English nonword repetition with stress and English nonword repetition without stress were decomposed for finer analysis to see whether they differed in the stress and pronunciation levels.

Approach Two: syllable pronunciation and stress/tone separately scored

In Approach Two, stress/tone was separately scored from syllable pronunciation to show the independent effect of stress/tone in nonword repetition. Each nonword repetition was transcribed and analyzed under four conditions: English stress (with stress), English pronunciation (with stress), English stress (without stress), English pronunciation (without stress).

Descriptive statistics. Table 4 displays students' performance on English reading and phonological working memory measures. Ability to reproduce English stress was higher on stressed nonwords [English stress (with stress)] than unstressed nonwords [English Stress (without stress)]. Conversely, reproduction of Chinese tone was better when all the syllables were presented in flat or first tone [Chinese tone (without tone)] than when the tone of the syllables varied [Chinese tone (with tone)]. Moreover, Table 4 also showed that a ceiling effect on English stress with stress (mean = .99, maximum = 1.00).

Correlations between variables. Correlations among all the measures are presented in Table 5. First, Chinese word learning significantly correlated with Chinese pronunciation with tone and Chinese pronunciation without tone ($r = .50$, $p<.01$; $r = .38$, $p<.05$, respectively). Moreover, Chinese word learning correlated significantly with English pronunciation with stress and without stress ($r = .51, p<.05$; $r = .55, p<.01$, respectively) as well. Also, the correlation between Chinese pronunciation with tone and without tone was significant ($r = .87, P<.01$), indicating much content overlapped between these two measures.

Results from multiple regression analyses. To find out which measures can predict Chinese word learning, multiple regression analyses were conducted. One predictor, English stress (with stress), was excluded from the regression model due to the performance ceiling, as shown in Table 4. Table 6 presents the predictors and R Square change in the model. The strongest predictors by step-wise model selection were English pronunciation without stress and Chinese pronunciation with tone. Approximately 43% of the variance of Chinese spoken word learning could be explained by the two predictors. Specifically, English pronunciation without stress accounted for 30% of the variance of Chinese word learning while Chinese pronunciation with tone explained an additional 13% of the variance. Considering that the two predictors might overlap, since both are measures of phonological working memory, the commonality between them was calculated. The calculation showed that 12% of the variance of Chinese spoken word learning could be explained by the overlapping part between Chinese pronunciation with tone and English pronunciation without stress. The unique contribution of English pronunciation without stress is 18% and the unique contribution of Chinese pronunciation with tone is 13%.

CHAPTER 4

DISCUSSION

The primary goal of this study was to investigate whether English-speaking children's phonological working memory can predict their ability to learn the pronunciations of Chinese words. The special feature of the present study is the participants had no previous exposure to the target language when this study was conducted, so their Chinese learning could not be mediated by existing knowledge of sound structure or vocabulary. This study is one of the first to investigate the effect of phonological working memory in learning a tonal foreign language such as Chinese.

Predictors of Chinese Word Learning

A major finding of this study is that repetition of both Chinese and English nonwords help predict English speaking children's Chinese word learning. The prediction is strongest when performance is scored without regard to whether the children correctly reproduce English stress or Chinese tone (Approach Two).

This finding is consistent with previous studies on the role of phonological working memory in foreign language learning. Moreover, it provides evidence that nonword repetition in both native and foreign languages can predict spoken word learning ability in the foreign language, even though the two languages differ greatly. Without a stored specification of the phonological structure of a word, a learner can neither recognize that word spoken by others nor produce that word in spontaneous speech. So, phonological working memory is crucial in mediating the processing of novel speech input, especially at the initial stages of vocabulary learning in a new language (Baddeley, Gathercole, & Papagno, 1998).

In addition to providing a temporary store for maintaining and processing verbal material (Baddeley & Hitch, 1974), phonological working memory mediates (at least in part) long-term learning of novel phonological forms by enabling a more stable sub-lexical representation (i.e., the phonological structure) of those forms in long-term memory (Gathercole & Baddeley, 1989, 1990; Baddeley, Gathercole, & Papagno, 1998). Both English nonword repetition and Chinese nonword repetition are reflections of phonological working memory capacity. Presumably, no matter in what kind of phonological forms (e.g. English or Chinese), superior phonological working memory enables children to grab more words before they slip by and thus making it possible to store them in long-term memory, though performance of different phonological forms might be affected by how familiar they sound to children. Nonword repetition in this study minimized available support children might get from existing knowledge. So, they had to rely mostly on phonological working memory. Therefore, learning of foreign words was directly constrained by capacity of phonological working memory, mainly demonstrated by English nonword repetition and Chinese nonword repetition.

A second major finding was that nonwords with unfamiliar phonological features were stronger predictors of Chinese word learning ability. As can be seen in Table 6, the best English predictor was repetition of unstressed nonwords. An item without stress is unnatural in English. The best Chinese predictor was nonwords with tone. Tone is an unfamiliar phonological feature for an American child. The finding that less familiar nonwords better predict children's ability to learn new foreign words converges with findings from previous studies (Gathercole, Willis, Emslie, & Baddeley, 1991; Yuzawa, Saito, Gathercole, Yuzawa, & Sekiguchi, 2010). As Miller (1956) stated, existing knowledge can increase chunk size thus enhancing the efficiency of phonological working memory. It makes big difference whether new phonological information can be chunked in performing memory tasks or not. While repeating familiar items, phonological memory information is supported by larger representations in long term memory. Thus, information can be retained more efficiently until processing can be completed, which lessens the burden of maintaining the entire phonological sequence of the nonword within the phonological loop, so the memory load is reduced. In other words, less demand is made on phonological working memory when nonwords contain familiar features. In contrast, less familiar items contain more novel phonological forms, thus information is chunked less efficiently. Consequently, not much lexical support is available from long-term memory, therefore children have to rely more on temporary storage function. Since not much association could be established between the memory task and existing knowledge, the memory load can not be reduced. It is speculated that with reducing memory load, generally the memory task becomes easier and thus children perform better. This accounts for why children's repetition of nonwords with a familiar feature (e.g. repetition of Stressed English nonwords) outperformed ones without this feature (e.g. repetition of Unstressed English nonwords). However, it is the less familiar items that best represent children's capacity to hold foreign words in working memory, because foreign words have few (if any) familiar features and children had to rely more on pure memory for remembering words.

Word length effect

Replicating previous research (Gathercole, Willis, Emslie, & Baddeley, 1991; Baddeley, , Gathercole, Papagno, 1998), repetition of both English and Chinese nonwords showed the word length effect (See Figure 1, Figure 2). Generally the longer words are, the longer it takes to perceive, encode, and rehearse them. As a word's length increases, the time reader spends fixated on it also increases. Readers spend approximately 30 extra milliseconds fixated on a word for each additional letter (Just & Carpenter, 1980). However, it is not always true that longer words take long time to be processed. This pattern changes, when words or letter patterns become so well learned that they are recognized as visual or audio wholes rather than individual phonemes or letters. As words and letter or sound patterns become recognizable as units for reading or listening, the capacity required to process them decreases. Presumably, then, more space in working memory becomes available for other cognitive activities (Just & Carpenter, 1980).

Joint effects of language and number of Syllables

Figure 5 shows that English nonword repetition was higher than Chinese nonword repetition at the 4-syllable level, but at the 2- and 3 syllable level, repetition of Chinese was slightly better than English, though the differences were not significant. This result suggests that when phonological working memory task became more challenging, repetition of English is easier than repetition of Chinese.

An explanation for the result is that knowledge of English morphemes and phonotactics facilitates chunking, and reduces the demands on working memory. The facilitation is stronger in more challenging English nonword items containing 4 or 5 syllables. For example, the English nonword *reutterpation* contains the word *utter,* the morpheme *re,* which appears at the beginning of many English words, and the familiar suffix *tion*, all of which can be encoded as chunks. Chunking is easier when the second syllable, *utter*, is stressed. However, compared with English nonword, an American child does not know any Chinese morphemes in Chinese nonword. Thus, a 4-syllable Chinese word is a string of arbitrary syllables that is not easily chunked. At 2- and 3-syllable level, the items are within the working memory capacity of most children, so whether the items can be readily chunked or not makes less difference. Children did not need to engage in as much processing as they did in with the longer nonwords.

The facilitating function of knowledge of morphemes in English nonword repetition can be demonstrated in the following ways. The first is difference in knowledge of morphemes. Comparing the structure of English and Chinese nonwords (Appendix D, Appendix E), the structure of English nonwords and Chinese nonwords differs greatly in known morphemes. Many English morphemes such as *-tion, -er, -ing, -ist, -ish* are contained in the English nonwords whereas there are no known English word parts in the Chinese nonwords (except for "*day"*, but the tone added to it makes it still challenging). Moreover, although a few English nonwords contained non-morphemes or had actual morphemes occurring in illegal positions, many English morphemes occurred in their expected legal positions. Particularly, many endings of these nonwords were actually suffixes in English, which made it easier to encode and rehearse the English nonwords, since meaningful chunks can increase working memory efficiency (Miller, 1956). The second difference is knowledge of English phonotactics, or knowledge of the allowable position and sequence of phonemes within English syllables. The American children in the present study were familiar with English phonotactics but knew nothing about Chinese phonotactics. Even English nonwords might sound "word like" to American children. The permissible Chinese phoneme combinations are different from English, English speakers did not know any of the formation rules of the sequence of sounds that form a Chinese syllable, thus Chinese words may sound totally strange to them. Though the syllables of the Chinese language are not phonologically complicated, it was still challenging for American children to string them together. This made it difficult for American children to hear or to speak Chinese. However, in order to get to the same level as they function in English, these children needed to develop a consciousness of phonotactics of Chinese (the phonological structure of Chinese syllables). But, these children did not know anything about the Chinese consonant and vowel combinations.

They also did not know any word structures and constraints such as which combination of consonants and vowels were possible and which are not. All the Chinese phonotactics was arbitrary to them when the present study was conducted.

However, the result that repetition of Chinese was slightly better than English at the 2- and 3-syllable level was unexpected. Presumably, the children were more familiar with English structures, thus the repetition of it should be better than Chinese at any syllable level. Several factors can account for this unexpected result. First, the phoneme difference between Chinese and English was minimized in the present study. As mentioned in the first chapter, Chinese and English have a different stock of phonemes. However, in designing items of Chinese Nonword Repetition, the present study avoided using phonemes that do not exist in English but are unique to Chinese (such as zh, sh,x), thus phonemic awareness should not be an issue in the present study. At least, it should not be the reason for Chinese nonwords repetition to be more difficult than English nonword repetition. Second, the duration time of Chinese 2- and 3-syllable nonwords might be longer than the corresponding English nonwords, thus providing a longer processing time for children to encode and temporarily store the phonological information. Most Chinese syllables have different tones, and tone changes might take longer time than English stress, since stress only falls on certain syllables within one nonwords. For example, comparing a 3-syllable Chinese nonword *bán liǔ hōu* and a 3-syllable English nonword *bannifer,* probably the former lasts longer than the latter, due to the fact that tone changes with each syllable within nonwords whereas English stress only falls on a certain part of the nonword. Additional study could help clarify this issue.

Stress and tone effects

As shown in Figure 1, at each syllable level, repetition of stressed English nonwords was higher than repetition of unstressed English nonwords, whereas repetition of Chinese nonwords without tone was higher than the repetition of Chinese nonwords with tone. In other words, stress facilitated English nonword repetition while tone hindered Chinese nonword repetition.

An explanation is that English speaking children are familiar with English stress, thus stress helps them organize and sequence the syllables and facilitates temporary storage. However, Chinese tone is new to these English speakers, thus it created a big challenge. Even when other phonological aspects were equal, the suprasegmental difference itself reflected by the difference between English stress and Chinese tone made it difficult for English-speaking children to learn spoken Chinese. The repetition of Chinese nonwords (even in repeating Chinese nonwords with flat tone) was challenging, so the extra work of repeating four tones competed and distracted children's attention from executing other aspects of the task.

Based on these findings, we might say English stress has no relationship with Chinese tone in second language acquisition. This result is consistent with Wang (2006) in that native and nonnative speakers of Mandarin show different patterns in the perception and production of Mandarin tones. Tonal pattern is an integral part of each word for native speaker acquiring Mandarin, but this functional association between segmental structure and pitch contour does not exist in non-tonal speakers' linguistic behavior. Two reasons can account for the difficulty in tone acquisition: one is nonnative speakers' lack of sensitivity to tonal categories, the other is the interference from L1 features, with knowledge of the function of pitch in the English stress and intonation systems highly influenced American listeners' perception of Mandarin tones.

Study Limitations

Several caveats must be considered when interpreting the results of this study. First, as shown in Table 3 and Table 6, much of the variance of Chinese spoken-word learning could not be explained. This is probably due in part to the fact that other factors, such as phonological awareness and general academic abilities as well as motivation also got involved in the Chinese word learning. As stated by Liu, McBride-Chang, Wong et al. (2010), word learning is a complex task that draws on many different cognitive skills and processes, thus phonological working memory could only account for some of the differences in Chinese learning. However, limited by the scope of the present study, other factors were not investigated.

Second, the measures of phonological working memory can be improved. Due to a performance ceiling, the English nonword repetition test, adapted from Gathercole, Willis, Baddeley and Emslie, was not ideally suited for measuring phonological working memory capacity for children in this study, since it showed the ceiling effect. Moreover, many known word parts occurred at their legal positions in this test, thus making the nonwords not “pure” nonwords. As for the Chinese word learning task, maybe more words should be included in this task or the opportunities to learn the words extended over several sessions. However, designing an appropriate Chinese word test was very challenging, considering the distinct phonological differences between English and Chinese and the fact that the participants had not been exposed to Chinese before. Several pilot studies were conducted before an appropriate Chinese word learning task was successfully designed. And, the pilot studies suggested that eight was the practical maximum number of Chinese words.

Third, the result of the present study might not be generalized until it can be replicated in further studies. Many explorations have been done on data analysis. Inferential statistics are based on hypotheses formulated in advance, however, this study involved many adjustments and several alternative approaches to analyzing the data were tried. Inferential statistics might lose its validity. It is important to have the findings replicated in the future.

Implications

To our knowledge, this study might be the first to investigate the Chinese word learning ability of children who do not speak Chinese from the prospective of phonological working memory. The finding extends the association of phonological working memory from related languages to phonologically distinct languages.

The findings in the present study are both theoretically and practically significant. Theoretically, they fill the gap in the previous research by showing that phonological working memory can predict the learning of a foreign language typologically very different from the native language. Moreover, finding a relationship between phonological working memory and Chinese word learning answers the criticism of the role of structural knowledge in nonword repetition argued by Snowling et al. (1991). The participants did not have any previous knowledge of Chinese, thus making the conclusion more convincing. The results suggest that the impact of phonological working memory on foreign language learning is not language-specific. Instead, it might serve as a general mechanism affecting learning of novel sound configurations, regardless of the similarity between native and foreign languages or previous exposure to the foreign language.

Finally, although presumably not as important as in listening, working memory capacity is also important in reading, since working memory for written material is primarily phonological in nature as well (Anderson, 2010). Therefore, the conclusion that phonological working memory can predict children's Chinese spoken word learning adds weight to the phonological working memory effect on the general foreign language learning.

In addition to the theoretical significance, the present study has practical implication for curriculum design and instructional practices for teaching Chinese as well. Chinese has been considered as one of the critical languages by the U. S. government and an increasing number of American K-12 schools offer Chinese as a foreign language. A test that successfully predicts whether children can learn Chinese words will be useful to parents, teachers, and school administrators in deciding which children can profit from Chinese instruction. It is necessary to understand the important factors in Chinese learning, so educators can seek strategies to help children. Since phonological working memory is important in learning spoken Chinese, then the inclusion of training aimed at developing phonological working memory should be beneficial for Chinese language learners.

The finding that tone had a negative effect on Chinese nonword repetition demonstrates that hearing tones is the most challenging task for English-speaking Chinese learners. Teachers might focus on strategies to develop children's sensitivity to Chinese tone, in order to help them learn Chinese more efficiently. Based on working memory capacity, teachers can specifically try the following strategies in curriculum design and instructional practices: practicing tone frequently to increase children's exposure to it, trying various strategies such as rhythm, tone twisters, and songs to reinforce children's memory trace for words in which hearing and producing tone is difficult.

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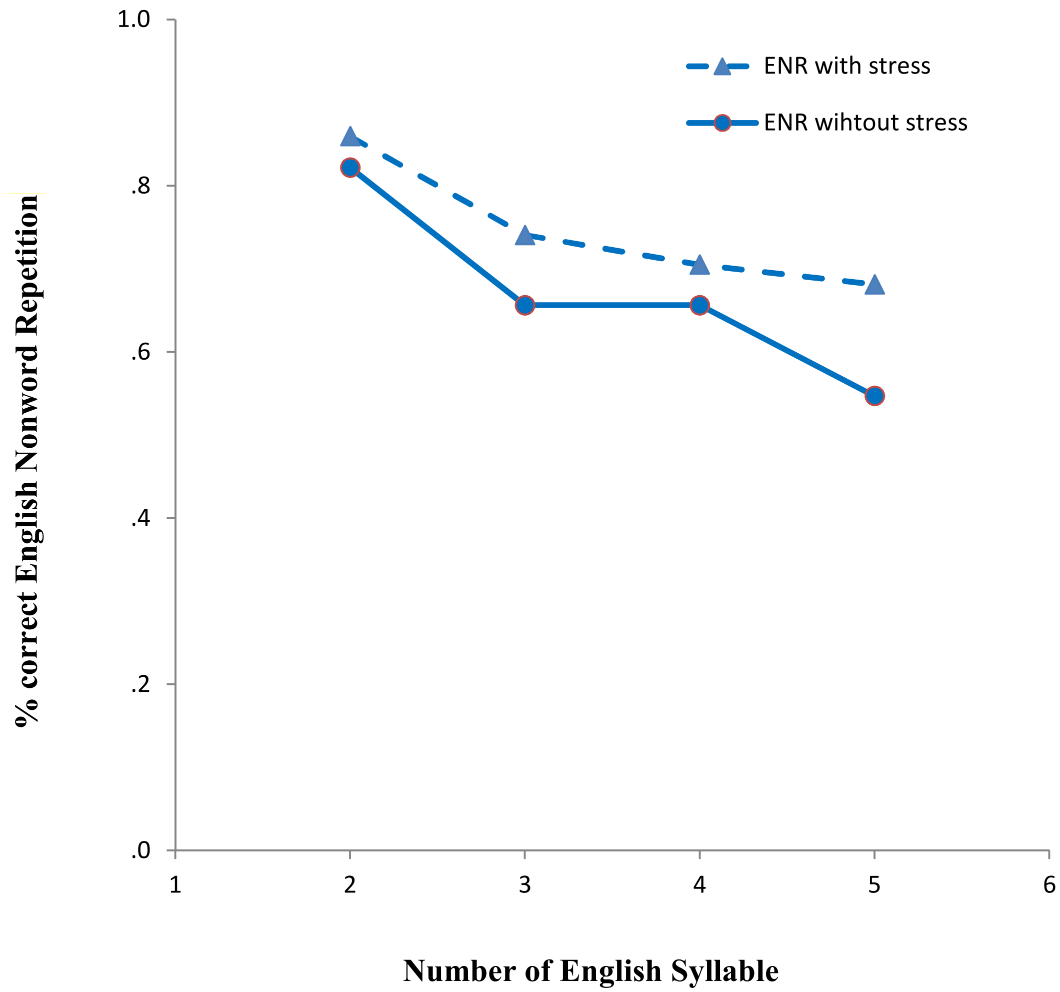
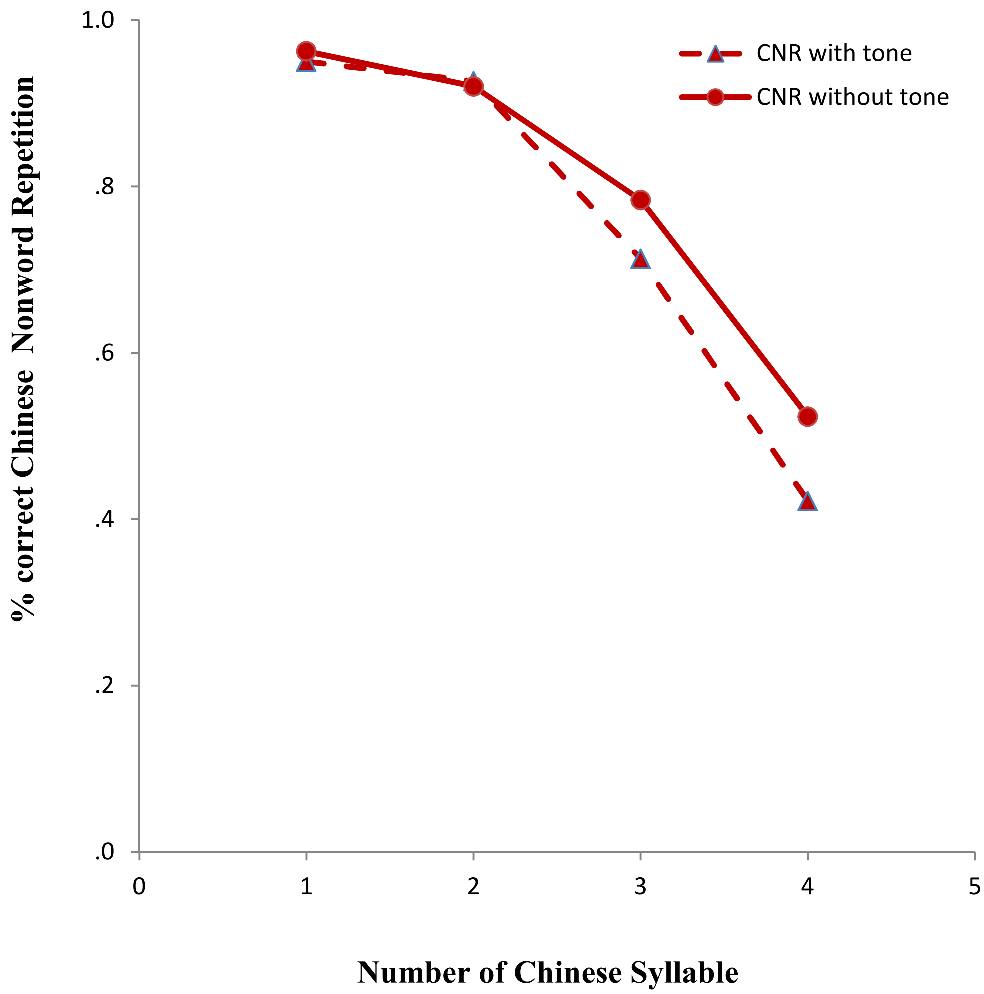
APPENDIX A: TABLES AND FIGURES

Figure 1 English Nonword Repetition as Function of Syllable & Stress Effect



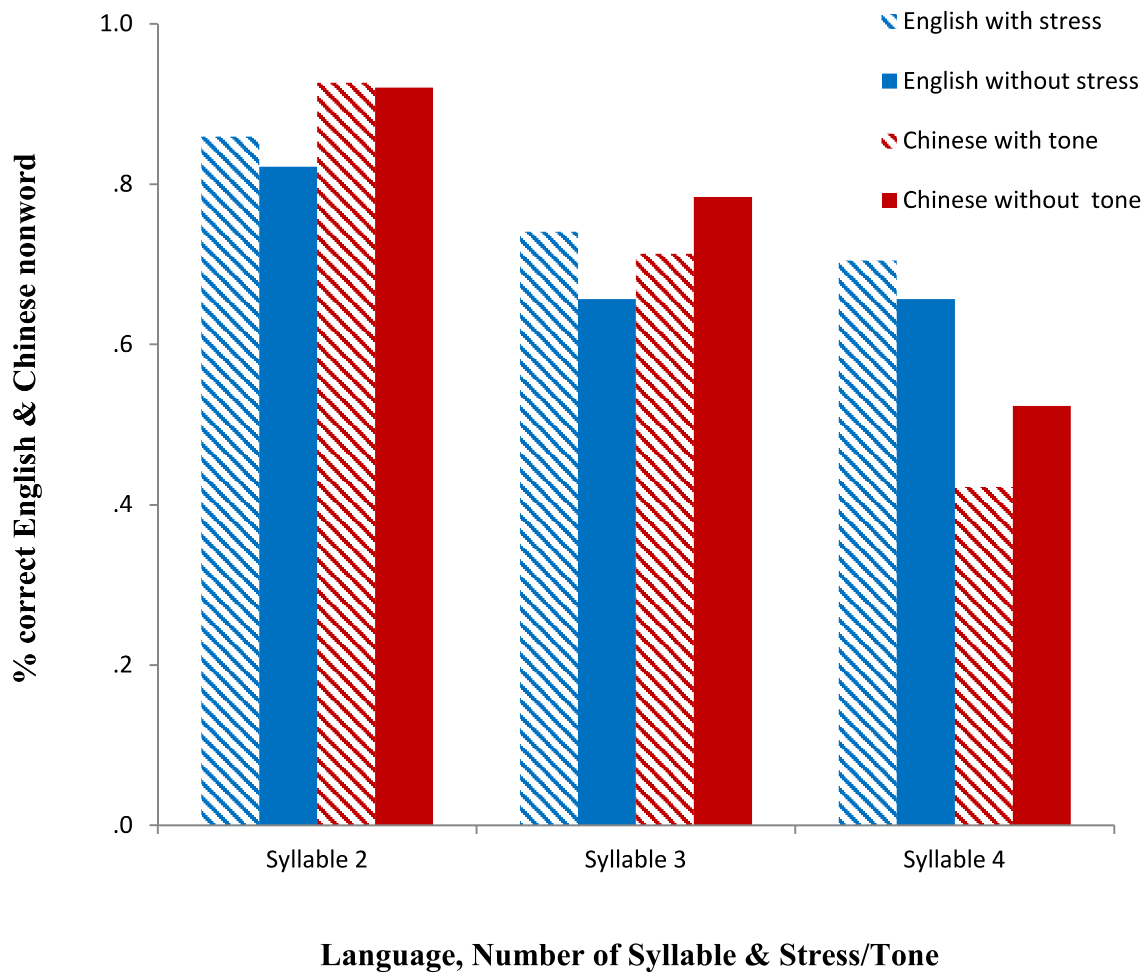
Note: The syllable effect and stress effect on performance of repetition is demonstrated by proportion correct score. The horizontal axis represents 2-, 3-, 4-, and 5-syllable English nonwords. The vertical axis represents proportion correct of performance on English nonword repetition.

Figure 2   Chinese Nonword Repetition as Function of Syllable & Tone Effect



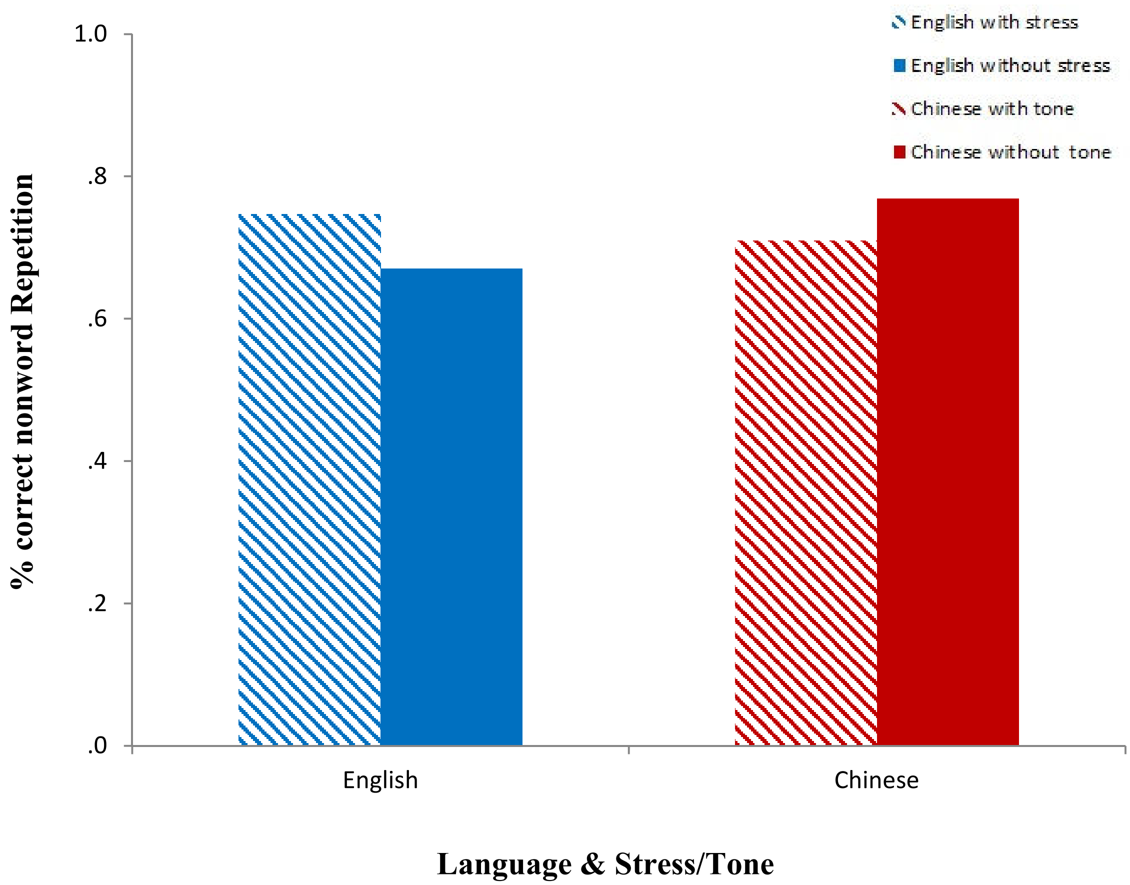
Note: The syllable effect and tone effect on performance of repetition is demonstrated by proportion correct score. The horizontal axis represents 1-, 2-, 3-, and 4-syllable Chinese nonwords. The vertical axis represents proportion correct of performance on Chinese nonword repetition.

Figure 3 Nonword Repetition as Function of Language, Number of Syllables, and Stress/Tone



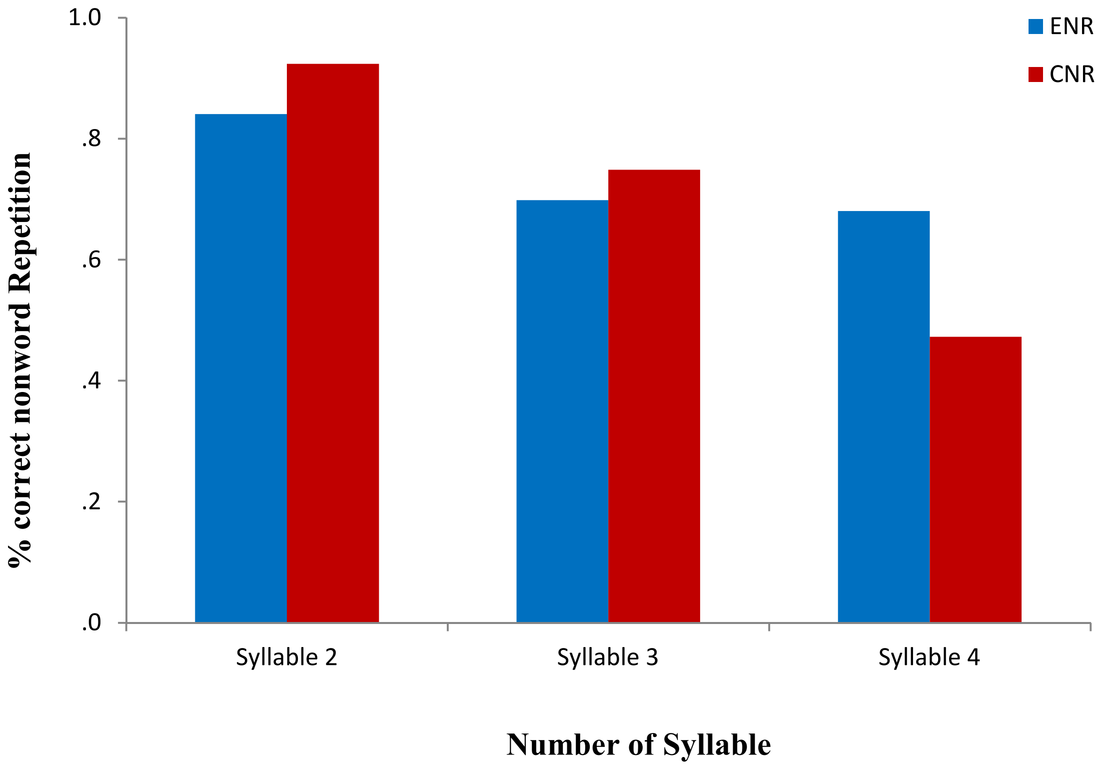
Note: The language effect, syllable effect and stress/tone effect is demonstrated by proportion correct score. The horizontal axis represents 2-, 3-, and 4-syllable both English (with & without stress) and Chinese nonwords (with &without tone). The vertical axis represents proportion correct of performance on both English and Chinese nonword repetition.

Figure 4 Nonword Repetition As Function of Language & Stress/Tone



Note: The stress/tone effect on English/Chinese nonwords is demonstrated by proportion correct score. The horizontal axis represents all the English nonwords (with & without stress) and Chinese nonwords (with &without tone). The vertical axis represents proportion correct of performance on both English and Chinese nonword repetition.

Figure 5   Nonword Repetition As Function of Language & Number of Syllable



Note: Performance of repetition on 2-, 3-, and 4-syllable English and Chinese nonwords is demonstrated by proportion correct score. The horizontal axis represents 2-, 3-, and 4-syllable both English and Chinese nonwords. The vertical axis represents proportion correct of performance on both English and Chinese nonword repetition.

Approach One

Table 1

Means, Standard Deviations, Maximums Possible, Minimums, and Ranges (N=32)

	Mean	SD	Maximum Possible	Actual Minimum	Range
English Reading Comprehension	.65	.23	1	.09	.91
Auditory Digit Span	5	.76	7	4	3
ENR with stress (syllable345)	.71	.11	1	.38	.52
ENR without stress (syllable345)	.62	.14	1	.38	.45
CNR with tone (syllable 34)	.63	.14	1	.38	.51
CNR without tone (syllable 34)	.71	.13	1	.42	.51
Chinese Word Learning	.45	.16	1	.06	.69

Note: 1. ENR = English nonword repetition, CNR = Chinese nonword repetition

2. Both English nonword repetition and Chinese nonword repetition use **PERCENTAGE** score

3. English nonword repetition with 3-, 4-, & 5-syllable nonwords

4. Chinese nonword repettion with 3- , & 4-syllable nonwords

5. The number of Chinese words correctly recalled in the final round was used as index of Chinese word learning

Table 2

Pearson Inter-correlations among English Reading Comprehension, Phonological Working Memory Measures and Chinese Word Learning (N=32)

		1	2	3	4	5	6	7
1	English Reading	_						
2	Auditory Digit Span	.28	_					
3	ENR with stress (syllable_345)	.19	.25	_				
4	ENR without stress (syllable_345)	.47**	.48**	.31	_			
5	CNR with tone (syllable_ 34)	.00	.47**	.22	.11	_		
6	CNR without tone (syllable_ 34)	.15	.55**	.36*	.15	.78**	_	
7	Chinese Word Learning	.19	.34	.45*	.39*	.47**	.39*	_

* P< .05; ** P< .01

Note: 1. ENR = English nonword repetition, CNR = Chinese nonword repetition

2. Both English nonword repetition and Chinese nonword repetition use PERCENTAGE score

3. English nonword repetition use 3-, 4-, & 5-syllable nonwords

4. Chinese nonword repettion use 3-, & 4-syllable nonwords

5. The number of Chinese words correctly recalled in the final round was used as index of Chinese word learning

Table 3

Multiple Regression analyses of performance on Baseline English Reading, Phonological Working Memory, and Chinese Word Learning (N=32)

Model One	ΔR2	Beta	t	Sig.
CNR (with tone)_S34	0.22	0.39	2.50	0.02
ENR(with stress)_S345	0.12	0.36	2.36	0.03

	ΔR2	Beta	t	Sig.
ENR (with stress)_ S 345	0.20	0.36	2.36	0.03
CNR(with tone)_ S34	0.14	0.39	2.50	0.02

Model Two	ΔR2	Beta	t	Sig.
CNR (with tone)_S 34	0.22	0.43	2.82	0.01
ENR (w/o stress)_S345	0.11	0.34	2.24	0.03

	ΔR2	Beta	t	Sig.
ENR (w/o stress)_S 345	0.15	0.34	2.24	0.03
CNR(with tone)_ S 34	0.18	0.43	2.82	0.01

Note:

CNR = Chinese Nonword Repetition   ENR = English Nonword Repetition

For Model Two:

1. Predictors: English Nonword Repetition (without stress), Chinese Nonword Repetition (with tone)
2. Dependent Variable: Chinese Word Learning
3. Communality = 0.33-0.11-0.18 = 0.03

Unique contribution of Chinese Nonword Repetition (with tone): .18

Unique contribution of English Nonword Repetition (with tone): .11

Approach Two

Table 4

Means, Standard Deviations, Maximums Possible, Minimums, and Ranges (N=32)

	Mean	*SD*	*Maximum Possible*	*Actual Minimum*	*Range*
English Reading	*.65*	*.23*	*1*	*.09*	*.91*
Auditory Digit Span	*5.00*	*.76*	*7*	*4*	*3*
ENR_345_pro_stress	*.71*	*.11*	*1*	*.38*	*.48*
ENR_345_Stress_Stress	*.99*	*.02*	*1*	*.93*	*.07*
ENR_345_pro_w/o stress	*.70*	*.12*	*1*	*.45*	*.41*
ENR_345_stress_w/o stress	*.90*	*.11*	*1*	*.62*	*.38*
CNR_34_pro_Tone	*.74*	*.12*	*1*	*.46*	*.46*
CNR_34_Tone_Tone	*.79*	*.11*	*1*	*.57*	*.40*
CNR_34_pro_w/o Tone	*.73*	*.11*	*1*	*.50*	*.43*
CNR_34_Tone_w/o Tone	*.94*	*.08*	*1*	*.71*	*.29*
Chinese Word Learning	*.45*	*.16*	*1*	*.06*	*.69*

* P< .05, ** P< .01 (2-tailed).
Listwise N=32

Note:
CNR = Chinese Nonword Repetition
ENR = English Nonword Repetition

Table 5

Pearson Inter-correlations among Initial English Reading, Phonological Working Memory Measures and Chinese Word Learning (N=32)

	1	2	3	4	5	6	7	8	9	10	11
English Reading	_										
Auditory Digit Span	.28	_									
ENR_345_pro_stress	.22	.30	_								
ENR_345_Stress_Stress	-.12	-.14	-.16	_							
ENR_345_pro_w/o stress	.57**	.44*	.44*	-.32	_						
ENR_345_stess_w/o stress	-.01	.17	-.02	.18	-.14	_					
CNR_34_pro_Tone	.01	.49**	.41*	-.23	.29	-.22	_				
CNR_34_Tone_Tone	.10	.41*	.18	.03	.37*	-.11	.73**	_			
CNR_34_pro_w/oTone	.13	.61**	.41*	-.07	.29	-.09	.87**	.61**	_		
CNR_34_Tone_w/oTone	.16	.25	.33	-.01	.40*	-.14	.56**	.60**	.61**	_	
CWL_N	.19	.34	**.51****	-.31	**.55****	-.18	**.50****	**.42***	**.38***	**.41***	_

Note: CNR = Chinese Nonword Repetition ENR = English Nonword Repetition

Table 6

Multiple Regression Analyses of performance on Baseline English Reading, Phonological Working Memory, and Chinese Word Learning

Model	ΔR2	Beta	t	Sig.
English Pronunciation (w/o stress)_S345	0.30	0.44	3.01	0.01
Chinese Pronunciation (with tone)_S34	0.13	0.37	2.52	0.02

Model	ΔR2	Beta	t	Sig.
Chinese Pronunciation (with tone)_S34	0.25	0.37	2.52	0.02
English Pronunciation (w/o stress)_S345	0.18	0.44	3.01	0.01

Note: N=32

1. Predictors: Chinese Nonword Repetition with Tone (syllable 3 & 4)
   English Nonword Repetition without Stress (syllable 2, 3 & 4)
2. Dependent Variable: Chinese Word Learning
3. Communality =.43-.13-.18 =.12
   unique contribution of English pronunciation without stress: .18
   unique contribution of Chinese pronunciation with tone: .13

APPENDIX: B

Pre-Questionnaire

Research Survey for Students Background Information

School: ___________ **Class**: Mrs. /Mr. ___________

1. Student Name: ___________

2. Birthday: month____ date____ year____

3. Race: White
Black/African American
Hispanic/Latino
Asian (Chinese, Korean, Japanese, Filipino, Vietnamese) or Other Asian (please specify)______

4. Language you speak at home with your parents:
English Spanish Chinese
Other languages (please specify)_______

APPENDIX: C

Digital Span

3-digit	4-digit	5-digit	6-digit	7-digit
2 9 4	3 8 2 9	6 1 7 3 8	5 7 1 4 2 9	9 6 1 5 8 2 7
6 8 3	6 1 5 7	5 2 4 9 7	4 8 3 9 6 2	3 5 8 1 4 2 6
7 1 5	4 9 2 5	3 6 1 8 5	6 1 7 3 5 8	7 4 1 6 3 9 2

APPENDIX: D

English Nonwords (Block A)

Item No.	Nonwords	Pronunciation	Student answer		**Note**
			Correct( )	Wrong ( )	
59	Defermication				
130	Bannifer				
37	Skiticult				
132	Brasterer				
35	Frescovent				
48	Stopograttic				
49	Woogalamic				
58	Voltularity				
140	Blonterstaping				
27	Rubid				
123	Glistow				
142	Contramponist				
36	Glistering				
134	Doppelate				
152	Detratapillic				
121	Bannow				
39	Trumpetine				
144	Fenneriser				
46	Pennerriful				
28	Sladding				
25	Pennel				
47	Perplisteronk				
45	Loddenapish				
143	Empliforvent				
151	Confrantually				
120	Ballop				
38	Thickery				
55	Sepretennial				
131	Barrazon				
29	Tafflest				
124	Hampent				
150	Altupatory				
122	Diller				
141	Commeecitate				
26	Prindle				
153	Pristoractional				
56	Underbrantuand				
133	Commerine				
154	Reutterpation				
57	Versatrationist				
Note: Bolded nonwords are pronounced with stressed tone, unbolded nonwords are pronounced with flat tone.					

Adapted from "The Children's Test of Nonword Repetition: A test of phonological working memory ," by Gathercole, S., Willis, C., Baddeley, A., and Emslie, H, 1994, *Memory, 2,* p. 103-127.

APPENDIX: D

English Nonwords (Block B)

Item No.	Nonwords	Pronunciation	Student answer		Note
			Correct( )	Wrong ( )	
139	Trumpetine				
43	Empliforvent				
127	Rubid				
33	Commerine				
44	Fenneriser				
146	Pennerriful				
54	Reutterpation				
22	Diller				
126	Prindle				
158	Voltularity				
20	Ballop				
41	Commeecitate				
23	Glistow				
42	Contramponist				
136	Glistering				
34	Doppelate				
125	Pennel				
40	Blonterstaping				
155	Sepretennial				
148	Stopograttic				
128	Sladding				
159	Defermication				
149	Woogalamic				
51	Confrantually				
137	Skiticult				
21	Bannow				
50	Altupatory				
31	Barrazon				
135	Frescovent				
147	Perplisteronk				
157	Versatrationist				
138	Thickery				
145	Loddenapish				
32	Brasterer				
156	Underbrantuand				
24	Hampent				
30	Bannifer				
53	Pristoractional				
129	Tafflest				
52	Detratapillic				
Note: Bolded nonwords are pronounced with stressed tone, unbolded nonwords are pronounced with flat tone.					

Adapted from "The Children's Test of Nonword Repetition: A test of phonological working memory ," by Gathercole, S., Willis, C., Baddeley, A., and Emslie, H, 1994, *Memory, 2,* p. 103-127.

APPENDIX: E

Chinese Nonwords (Block A)

1-syllable	2-syllable	3-syllable	4-syllable
mō	nǔ tài	Gē diù mù	Yáo' óu pìn biǎo
bǎ	*Tōu wā*	*Māo lān kōu*	*Kē niāo wān fā*
niū	Mán pěi	*gēi tī līn*	Pài' ěi lāo kán
yǒu	Lī nāo	Pěn gòu fó	*Dā bū kēi huō*
pào	*Bīn gāi*	*Wēn kuō nī*	*Mēi dōu hāo gū*
hēn	Dǎo huǎ	*Nēi lūn kuā*	Bāi tuí lā nè
léi	*Fān bō*	*Fēi guī tuō*	
wāi	Dú 'í	Bán liǔ hōu	
dān	*Mēn kā*	*Bī fōu hē*	
fū	*Hēi lān*	Hǎ mái děi	
		Dēn lōu hāi	
		Tà lú piào	
		Mín diàn hū	
		Wō tē yīn	
		Dā mī bēn	
		Bāo pò yē	
		Kāo gā lē	
		Lài nín ' é	
		Tú fēn pá	
		Yǎ pū gàn	

APPENDIX: E

Chinese Nonwords (Block B)

1-syllable	2-syllable	3-syllable	4-syllable
dān	Fàn bō	Mào làn kǒu	*Pāi' ēi lāo kān*
hèn	*Mān pēi*	*Bān liū hōu*	Mēi dòu hào gú
lēi	Bīn gāi	Dā mī bén	*Yāo' ōu pīn biāo*
mō	*nū tāi*	*Lāi nīn' ē*	Dǎ bù kèi huō
bā	*Dū 'ī*	*Bāo pō yē*	Kě niāo wán fā
fǔ	Mēn ká	gēi tǐ lín	*Bāi tuī lā nē*
niú	*Lī nāo*	Kǎo gā lè	
yōu	Tòu wà	Bǐ fóu hě	
wài	*Dāo huā*	*Yā pū gān*	
pāo	Héi làn	*Mīn diān hū*	
		Néi lún kuà	
		Hā māi dēi	
		Wèn kuō nī	
		Pēn gōu fō	
		Wǒ tè yǐn	
		Dén lōu hǎi	
		Tū fēn pā	
		Tā lū piāo	
		Gē diū mū	
		Fèi guǐ tuō	

APPENDIX: F:

Chinese Word Learning (Group One)

0	dog **gǒu**	aunt **ā yí**	apple **píng guǒ**	rice **dà mǐ fàn**
1	aunt **ā yí**	dog **gǒu**	rice **dà mǐ fàn**	apple **píng guǒ**
2	rice **dà mǐ fàn**	aunt **ā yí**	apple **píng guǒ**	dog **gǒu**
3	apple **píng guǒ**	rice **dà mǐ fàn**	dog **gǒu**	aunt **ā yí**
F 4	dog **gǒu**	apple **píng guǒ**	aunt **ā yí**	rice **dà mǐ fàn**
5	aunt **ā yí**	dog **gǒu**	rice **dà mǐ fàn**	apple **píng guǒ**
6	rice **dà mǐ fàn**	aunt **ā yí**	apple **píng guǒ**	dog **gǒu**
7	apple **píng guǒ**	rice **dà mǐ fàn**	dog **gǒu**	aunt **ā yí**
8	dog **gǒu**	apple **píng guǒ**	aunt **ā yí**	rice **dà mǐ fàn**
9	aunt **ā yí**	dog **gǒu**	rice **dà mǐ fàn**	apple **píng guǒ**
10	rice **dà mǐ fàn**	aunt **ā yí**	apple **píng guǒ**	dog **gǒu**

APPENDIX: F

Chinese Word Learning (Group Two)

group 2				
0	tiger **hǔ**	hair **tóu fà**	we **wǒ mēn**	glass **bō lí bēi**
1	we **wǒ mēn**	tiger **hǔ**	glass **bō lí bēi**	hair **tóu fà**
2	tiger **hǔ**	hair **tóu fà**	we **wǒ mēn**	glass **bō lí bēi**
3	hair **tóu fà**	glass **bō lí bēi**	tiger **hǔ**	we **wǒ mēn**
F4	glass **bō lí bēi**	we **wǒ mēn**	hair **tóu fà**	tiger **hǔ**
5	we **wǒ mēn**	tiger **hǔ**	glass **bō lí bēi**	hair **tóu fà**
6	tiger **hǔ**	hair **tóu fà**	we **wǒ mēn**	glass **bō lí bēi**
7	hair **tóu fà**	glass **bō lí bēi**	tiger **hǔ**	we **wǒ mēn**
8	glass **bō lí bēi**	we **wǒ mēn**	hair **tóu fà**	tiger **hǔ**
9	we **wǒ mēn**	tiger **hǔ**	glass **bō lí bēi**	hair **tóu fà**
10	tiger **hǔ**	glass **bō lí bēi**	hair **tóu fà**	we **wǒ mēn**

APPENDIX: F

Chinese Word Learning (Final Test)

English- Chinese	apple **píng guǒ**	hair **tóu fà**	tiger **hǔ**	rice dà mǐ fàn	dog **gǒu**	aunt **ā yí**	glass **bō lí bēi**	we **wǒ mēn**